

PLACO: a Cooperative Architecture for Managing Workflow in CCU

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Computer-Supported Cooperative Work (CSCW) is a multi-disciplinary research theme involving software developers, computer scientists, as well as psychologists and sociologists. CSCW is devoted to the analysis of interactions among humans when performing their work in a collaborative way. The main application fields are work organization, healthcare, education and training. The term of Groupware, as defined by C.A. Ellis, refers to software that assists groups of people in communicating, in collaborating and in coordinating their activities. Our objective is to study software architectures allowing task coordination and conflict management between participants within a distributed environment, in particular medical units. We do not aim to produce a practical system suitable for near-term deployment in the Critical Care Unit (CCU), but rather a "proof of concept", an experimental system that performs and coordinates a range of intelligent planning tasks in CCU activities. The emphasis will be put especially on asynchronous cooperation since the work of physicians and nurses is discontinuous.

INTRODUCTION

In critical care environment, a growing body of research has been developed aiming at improving intensive care with computer-based systems [3]. Much of these systems offer practical solutions to CC problems. But, current research in medical informatics neglects the factor of human cooperation. This fact is probably one of the multiple causes of the failure of computer systems dedicated to medical field. In addition, the absence of a common tool for exchanges between physicians and nurses causes a multiplication of paper supports for the recording of information. For this purpose, we are motivated to modelize CCU activities and propose a cooperative architecture.

PLACO (PLAnification COopérative, i.e. Cooperative Planning) is a computer-based system which supports the cooperative planning in CCUs. The objectives of PLACO are to analyze the tasks and to introduce the concept of Computer-Supported Cooperative Work (CSCW) in the design of dedicated medical systems.

The PLACO approach covers theoretical, technical and practical aspects; from the phase of investigating

models to the phase of designing and evaluating a prototype.

In this paper, we will:

- propose a model of cooperation in CCU based on the workflow theory [7].
- propose an example of cooperation scenario with the actors: the physician, the headnurse and the nurse.
- develop a cooperative architecture to support the model.

THE CONCEPTUAL FRAMEWORK OF PLACO

Cooperative work

Team work is the essence of medical and nursing activities in CCUs. People cooperate to collect data, to exchange information. They share responsibilities, delegate activities. Co-decision and task coordination are the main rule. The lifeblood of an organization is not data or computation [7]; it is interaction among the team members and with the external world: hospital management, laboratory, imaging departments, etc. The essential elements are people and the actions they carry out.

Breakdowns

We call «breakdowns» deviations from the normal safe course of things. They do not necessarily mean catastrophic or harmful events, but just disturbing or potentially harmful deviations of what is the normal operation of a CCU. The breakdowns come from synchronization failures between people, or from the absence of useful information, or from abnormalities in its transmission (excess of information, partial or total lack of data, distortion during the exchanges, no clear decisions are taken).

Example of a breakdown

During the visit, a drug is prescribed by the physician. But the nurse does not immediately write this prescription on the care notebook. Then, she is called to perform an urgent task and does not delegate this action to another nurse. Consequently, the treatment is not completed, and two hours later, the physician cannot evaluate the effect of the prescribed drug.

Considering the hypothesis that many breakdowns are the result of dysfunctions in human interactions [1,2], we think that groupware can be one of the efficient means for solving the problems connected with cooperation within the framework of medical units. Accordingly, we need to develop a conceptual model, in particular a model of human-human interaction in medical and nursing activities: deciding, organizing, acting, observing, reporting, assessing. Such a model is fundamental to understand the origin of conflicts and dysfunctions of a work team, to guide our investigations of those phenomena and, hence, to help the design of an adequate computer system.

Workflow model

The basic elements of coordinated work is the transfer of objects and information between two individuals. In addition, such a transfer always involves a transfer of responsibilities [4][6][7]. Among the various underlying paradigms, we are favoring the workflow analysis which is mainly based on the *Language/Action perspective* developed by **Winograd & Flores** [7], itself derived from the **Speech Act Theory** of **Austin and Searle** [5].

In the cooperative work perspective, human activities are grouped in scenarios, i.e. recurrent organizations of work in which personnel and resources are engaged. They have a goal, a start and a well-defined end. Scenarios involve "objects" such as data, documents, reports, messages. The objective when describing them is to highlight the structure in which work is completed. A scenario could be, for instance, a blood analysis, from the decision of the physician to order this analysis until the availability of the results in the patient's record and the acceptance of these results by the physician. We propose to modelize scenarios by the workflow cycle [8][9].

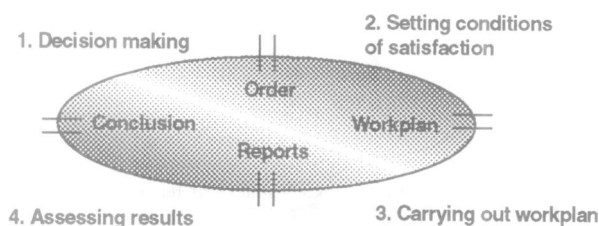


Figure 1. The phases and transitions of the WF Cycle.

The workflow cycle (WFC), as shown in figure 1, describes the activities of one or several individuals. It is the basic element of a scenario. The structure of a workflow cycle is made up of *four steps or phases* and *four transitions*. The first step is a request, an order or an offer. It is determined by the same individual when

he accepts the results of the work.

The workflow model presents the mediation of information by computerized systems which allow the control of information flows (coherence, availability, completeness, synchronization) to diminish or to suppress the current breakdowns. We shall use the model of the workflow cycle as a conceptual framework for interpreting breakdowns in critical care activities.

The four phases:

- *Phase 1*: the problem is stated and analyzed; a conclusion is drawn and a decision for action is taken.
- *Phase 2*: the decision is confronted with practical constraints.
- *Phase 3*: the action plan is carried out and the obtained results are observed and reported.
- *Phase 4*: the obtained results are assessed, i.e. compared with the expected ones.

The four transitions: They represent the control components of the workflow cycle. They authorize the shift from one phase to the next one.

- *Transition 1*: Acceptance of the decisions for action.
- *Transition 2*: Acceptance of the action plan.
- *Transition 3*: Acceptance of the activity report.
- *Transition 4*: Acceptance of the outcome of the confrontation between expectations and reality.

Instantiation of the Workflow model in CCUs

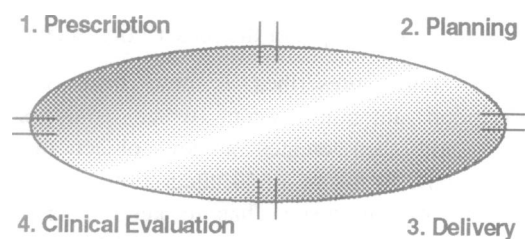


Figure 2. The instantiation of the WF Cycle.

In the case of the drug prescription (see the figure 2), the first phase corresponds to the prescription by a physician. The second phase is the organization of the treatment and therapy plan by the headnurse. The third phase is the delivery by the nurse. The fourth phase is the evaluation of the treatment by a physician.

The workflow model seems interesting to explain the breakdowns occurring in CCE during the treatment of the patient. The model showed that the most frequent errors occur during the transition between phases.

In our example, the breakdown occurred during the transition between the prescription by the physician and the planning by the nurse.

This model is essential to have a clear idea of the information flow between the actors in CCU before programming the groupware necessary to support the cooperation of physicians and nurses.

A SCENARIO OF COOPERATION

In this section, we will illustrate, by a simple example, our approach. We limit ourselves to a drug prescription scenario.

The phase of the prescription

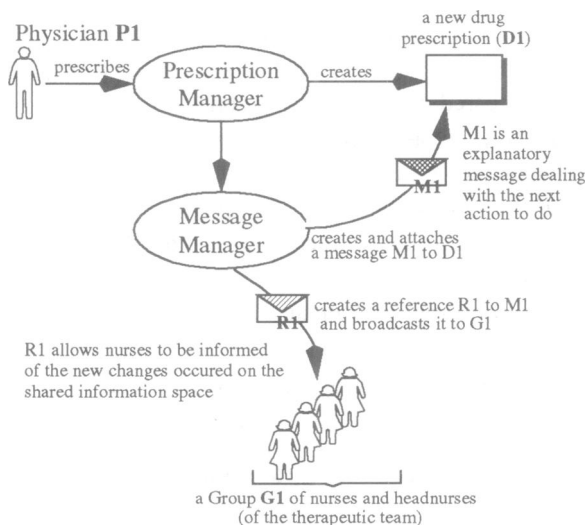


Figure 3. An example of the prescription scenario.

The physician prescribes a new drug via the prescription automatic agent which analyzes the request and then creates a new object (a drug prescription). To insure a real integration of workflow management, our system has to keep other actors informed of this action and to route useful information to the next involved actor, in this case the nurse.

As illustrated in figure 3, when a new prescription is created, it involves the Message Manager, an automatic agent specialized in managing messages. This Message Manager takes into account the creation of the prescription and generates a message, containing an explicative text, which will be associated to the drug prescription and stored in its mailbox. It also broadcasts a reference of this message to some predefined group of nurses or physicians.

This message will be kept in the mailbox until the next involved actor (i.e. a headnurse as shown in figure 4) will connect to the system.

The phase of the planning

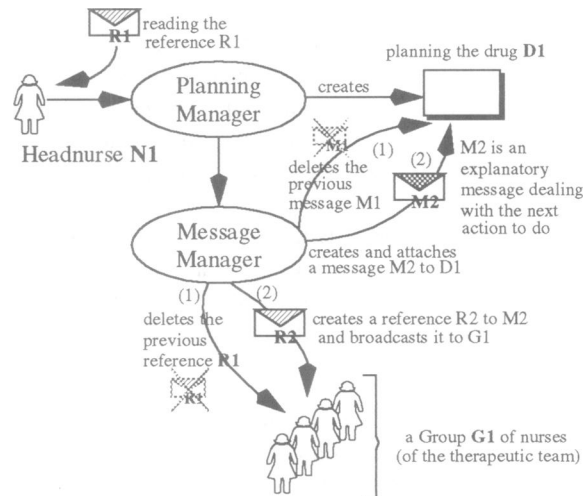


Figure 4. An example of the planning scenario.

The headnurse N1 becomes aware of all changes by the means of the message references, and organizes the therapy plan for the patient: the necessary drugs, the time of delivery, the rate of infusion.

The Message Manager updates messages and references by:

- deleting (cf. figure 4) those which are dealing with actions already performed (i.e. the prescription planning).
- creating a new reference and broadcasting it to the group G1 of nurses.

The phase of the delivery

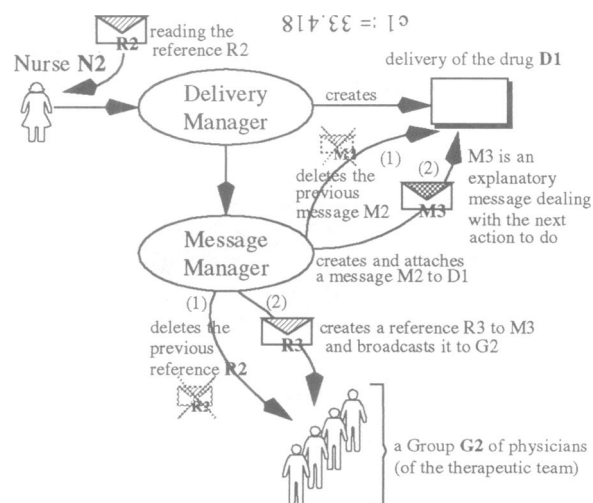


Figure 5. An example of the delivery scenario.

The scenario of the figure 5 is similar to the previous one. Indeed, the involved actor, the nurse N2, reads the

message M2 and completes her task which concerns the drug delivery according to the delivery times table scheduled in the previous phase. When she finishes this task, the message manager creates a new message M3 and links it to the drug D1. It also creates a reference R3 that it broadcasts to the group G2 of physicians for the clinical evaluation. During the delivery task, the nurse is able to create some relevant messages related to the patient status and his reaction to the drug delivery. The last phase corresponds to the assessment of the effect of the drug and leads either to renewing, removing or changing the prescription.

In conclusion, this technique allows:

- care-providers to be continuously informed of all the events and changes occurring in the patients' records,
- tasks to be well-defined and coordinated,
- and finally, a real integration of a new dimension; that is to say, the cooperation.

IMPLEMENTATION OF PLACO

To support this model we have defined a four-layers architecture (cf. figure 6) based on:

- the object-oriented paradigm,
- agents operating on an information space, shared by the different actors during the phases of a workflow cycle,
- messages for insuring a real communication between agents, and
- external events for guiding the organization of actions and messages.

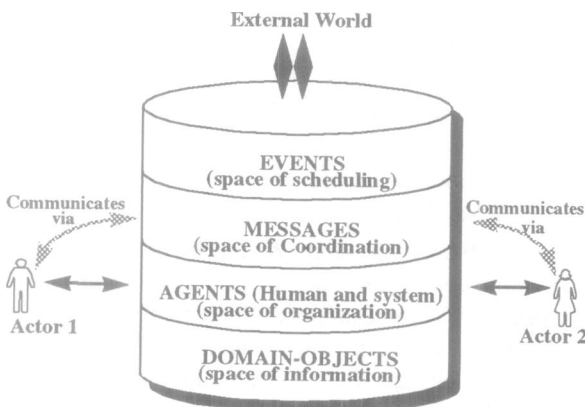


Figure 6. PLACO's architecture is implemented in four layers.

As illustrated in figure 6, there are four layers:

- the first layer is made of the domain-objects and represents the basis of the whole architecture and contains all the information objects.

- the second layer is the one of both automatic and human agents. It includes the dimension of organization.
- the third layer which contains messages and is dedicated to coordinate agents.
- the fourth level concerns the space of events. This layer communicates directly with external environment and contains agents specialized in classifying and scheduling all events.

As we use the object-oriented analysis, we define in PLACO three object models which are clarified below:

Domain-Object (space of information), **Agent** (space of organization and scheduling) and **Message** (space of coordination) and .

Domain-Object

A domain-object represents a piece of useful information, on which agents execute their tasks. When an object (i.e. domain-object) is handled, an explanatory message ("post-it") is created and associated to the involved object.

Agent

There are two types of agents in PLACO:

- human agents correspond to graphical and active user interfaces which allow the actor (physician or nurse) to have access to the PLACO system.
- automatic agents are a sort of intelligent and independant processes which have a role in the management of the workflow, that means in the sequence of the actions performed by different actors.

We use this approach to implement specialized agents, for instance, in message management (creation, sending, updating, etc.), in domain-object management (creation, modification, deleting, etc.), and so one. This idea involves a communication between agents, especially between human agents and automatic agents.

Message

It is the key-element of the coordination in PLACO. The essential role of message is to save the complementary information needed by actors to perform safely their tasks. Complementary information could be a simple explanation of a drug change in a prescription. This piece of information is very useful to the other members of the team to understand what is happening at any time. This approach makes actors of a given group permanently informed of all changes of domain-objects. Hence, they will act in a right way according to these changes, and then may avoid breakdowns and failures. All task traces and results are kept, in a shared space, for the next phases.

Prototype

A prototype, requiring further improvements, is currently under development. It represents the first part of a cooperative therapy plan, following the specifications resulting from the workflow model and users requirements. The man-machine interfaces have to be as attractive as possible:

- Using **Windows'** paradigm,
- Differentiating the interfaces according to the profile and the status of the connected person,
- Facilitating message acquisition and management

To permit an object-oriented approach, we have chosen to write the new prototype using **SMALLTALK/V** language, on PC workstations connected through Ethernet network to a sever of applications. PCs represent the clients. The main server contains the kernel of PLACO (spaces of agents). Domain-objects are distributed in clients because, in an CCU, actors require one workstation (PC) per patient.

CONCLUSION

CSCW and groupware are emerging fields of research and development that take into account the sociological dimension of work. Stand-alone computers have changed the life of millions of workers. CSCW applications will have the same impact on the life of the organizations.

The cooperative dimension of the work is obvious in Medical teams and particularly in Critical Care Units. The work realized in the PLACO project must have an impact on the conception and realization of the future pilots.

The benefits that users expect generally by using groupware are summarized as below:

- Better efficiency for the decision process,
- Time and money saving,
- Rapid solving of crisis situations,

In developing new applications, it will be essential to identify which parts of the software will be modified if we have a cooperative conception of the work. Consequently, some processes will be best candidates for implementation of groupware. As an example, for the management of CCU, the therapy plan could be a first trial for this new technology. And, identically, in the management of the therapy plan, some parts will not be subject to any changes (adverse effects, dose calculation, printing...). Consequently, after a comprehensive analysis of the organization, of the role of the actors, CSCW and groupware can be used for

focal applications in existing software to improve a concrete problem where cooperation is indispensable.

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